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FUEL-GAS.

A PAPER SHOWING THE IMPRACTICABILITY OF UTILIZING COAL-GAS FOR FUEL PURPOSES, BY J. F. MERKLE, C. E., INSTRUCTOR IN CIVIL ENGINEERING.

The subject of fuel-gas has been the theme of discussion of all the associations of gas engineers of this country and Europe for the past three years, and the lesson taught by these discussions, together with many experiments which have been made during this time, have not yet solved the problem of a successful artificial fuel-gas, but have rather marked a course which is not to be pursued. That gas may be used economically and safely for domestic purposes has been fully demonstrated in many parts of this country, where natural gas is the principal fuel used. In this connection, I may state that in Pittsburg there is consumed daily over four hundred million (400,000,000) cubic feet of natural gas, and so nicely are all the appliances adjusted that accidents are rare, and when they do occur they are usually the result of negligence.

By a fuel-gas I mean a gas which will displace coal as fuel in nearly all domestic and metallurgical operations. It can not be expected that gas will be used entirely for domestic purposes, no more than it can be expected that illuminating gas shall entirely displace oil, nor electricity the illuminating gas.

The first essential element of a fuel-gas in competition with coal, must naturally be an equivalent amount of heat for the same money. Of course there are many advantages which gas has over coal for domestic use, but these would have little influence

with the public unless the cost of gas was not more than that of coal. A few of these advantages, stated briefly, are: Cleanliness of the house, for with gas as a fuel, there is no dust and smoke arising from combustion; second, there is no inconvenience arising from being obliged to have the cellar filled with coal, no kindling wood to be purchased, and no ashes to be carted away.

In this paper all values of coal refer to the bituminous variety, since that is the coal used in gas manufacture, and in order to reduce everything to a basis for the sake of comparison, we must consider it as being used in general by the public.

Let us now ascertain how much heat is obtained from a ton of coal by the ordinary method of combustion. From experiments which were conducted by a company with which I was recently associated, it was ascertained that the heat utilized in the ordinary stove or range was only about twenty (20) per cent. of the theoretical calorific value of the coal. Ordinary bituminous coal contains about twenty-five million (25,000,000) heat units per ton. This heat unit is that used in England principally, and its value is the amount of heat necessary to raise one pound of water one degree Fahrenheit. In order to give you a true conception of this amount of heat I will say that it will raise twenty-six hundred and thirty (2630) cubic feet of water from 60 degrees Fahrenheit to 212 degrees. Now, from the results of the experiments concerning the combustion of coal in stoves, we see that of the twenty-five million (25,000,000) heat units contained in the coal we utilize only five million (5,000,000). This low result is due to the imperfect combustion of the coal and lack of regeneration in the stoves, together with the ignorance of the average man concerning the laws of combustion.

Now let us examine the results obtained from the combustion of gas in stoves specially constructed for its use. I have before me the results of experiments with several gas stoves, all made under the same conditions, and I find the maximum efficiency to be 99½ per cent., and the minimum 92 per cent. of the calculated theoretical calorific value of the gas, as determined by volumetric analysis. We may therefore consider 95 per cent. as a fair average of the efficiency of gas stoves.

Now assume the cost of coal delivered in the cellar to be $2 per ton; then in order to put fuel-gas on a competitive basis with coal, we must deliver the equivalent of one ton in heat units, or five million (5,000,000), for the same price, namely $2. Therefore,

if we know the calorific value of our gas, or in other words, if we know the number of heat units contained in a thousand feet, we can readily determine the amount which we can sell the gas for per thousand feet, in order to give the consumer the same return for an equivalent amount of money.

Let us now consider briefly the gases which are manufactured commercially for illumination and metallurgy, in order to ascertain the reason that none of these will answer our purposes for a fuel-gas. These gases are coal-gas and water-gas, which are made for illumination, and producer-gas which is used in metallurgical operations.

We will first consider the subject of coal-gas, and in this connection a brief history of the manufacture of this gas will not be amiss.

I quote the following from an English work on the subject: "By general consent, the mention of the discovery and application of artificial gas belongs to Great Britain, and the name most honorably connected with the beginning and early stages of gas lighting, is that of a Scotchman, Robert Murdoch. But previous to Murdoch's time, there occur numerous suggestions, observations and experiments, as to the inflammable air and its sources. In the "Philosophical Transactions of the Royal Society" for 1667, the existence of a burning spring in the coal district of Wigon is noticed by Thomas Shirley, who traced its origin to the underlying coal. In the same transactions for 1739, is printed a letter, addressed to Hon. Robert Boyle, who died in 1691, in which Rev. John Clayton details a series of experiments which he made in distilling coal in a retort, showing not only that he had observed the inflammable gases evolved, but that he collected and stored them for some time in bladders. In Dr. Stephen Hale's work on vegetable statistics published in 1726, more precise statements are made as to the distillation of coal, he having obtained from one hundred and fifty-eight (158) grains of New Castle coal, one hundred and eighty (180) cubic inches of inflammable air. In 1787 Lord DonDonald, in working a patent process for obtaining coal tar, experimented with the gas evolved in the process, and occasionally used it for lighting up the hall at Colroys Abbey. None of these observations led to practical results, and it was not until the year 1792 that Robert Murdoch, then residing in Redruth in Cornwall, began the investigation of the properties of gases, given out by various substances, which

eventuated in the use of coal gas as an illuminating agent. In 1797 he publicly showed the system he had matured, and in 1798, being in the employ of the famous workshop of Boulton, and Watt, he fitted up an apparatus for the manufacture of gas in that establishment, with which it was partly lighted. Thereafter it was introduced in neighboring workshops and factories.

"Among others who helped most materially in developing the infant art in England were Dr. Henry Manchester and Mr. Clegg, who succeeded Mr. Murdoch in the Soho Mills. Mr. Clegg introduced many improvements in gas manufacture, and ultimately became the most successful gas engineer in the United Kingdom. In 1801, Mr. Lebon introduced gas, distilled from wood, into his own house in Paris, and the success of his experiments attracted so much notice and comment as to give rise to the impression that he is entitled to the credit of the invention. Lebon's experiments came under the notice of Mr. F. A. Winsor who took up the subject with a zeal and unremitting patience, which led to the recognition of the advantages of the system, and the breaking down of the powerful prejudices which existed in England against the innovation. In 1803, through Winsor's efforts, the Lyceum Theatre was lighted with gas, but it was not until 1810 that he succeeded in forming a public company for gas manufacture."

Coal gas, which is the result of the destructive distillation of coal, is made in a fire-clay retort heated to incandescence. A coal gas plant consists essentially of a furnace, which contains the retorts, a scrubber, a condenser and a purifier. The retort in which the coal is distilled is usually about 9 feet long and its section represents an eclipse 26″ by 13″, flattened on the bottom. These retorts being heated sufficiently, the coal is charged into one end, the other being closed, and after a sufficient amount of coal has been charged, which is usually three hundred (300) pounds, the mouthpiece of the retort is closed to prevent the admission of air. Distillation immediately begins, and under ordinary circumstances continues for about four (4) hours. The result of this distillation is a gas containing hydrogen, marsh gas, carbonic oxide, olefiant gas, carbonic acid, nitrogen, oxygen, water vapor, sulphuric acid, a small percentage of sulphurretted hydrogen and ammonia, and a considerable amount of heavy hydrocarbons in the form of tar. There remains in the retort however, a large percentage of coke. This will vary according to the quality and character of coal used, and in the coals employed for

the manufacture of gas in this country, the result is usually about sixty-five (65) per cent. Before the gas is fit for consumption, the gases which are deleterious to health must be removed. These are the ammonia and the sulphurretted hydrogen. The ammonia is removed in an apparatus called the scrubber, which is constructed on the principle that water has a great affinity for ammonia. The scrubber consists usually of a wrought iron cylinder standing on one end, in which are arranged trays on which is placed either charcoal or scrap tin. The water is allowed to percolate freely through this, and the gas, admitted at the bottom, is broken up by the charcoal or tin into small globules, which, coming in contact with the water in its downward course, give up their ammonia to it. This water, now known as ammoniacal liquor, is carried off into a tank constructed for its reception.

The tar, which is held in suspension, liquefies when its temperature is sufficiently reduced, and for this purpose a large wrought iron cylinder, similar to the scrubber, is employed, through which, however, are many small tubes or pipes, placed longitudinally, and around the whole, water freely circulates. The gas, in passing through these small tubes, is diminished in temperature, owing to the conductivity of the iron and water, and the tar is liquefied and runs to the bottom, where it is collected and conducted off to what is known as the tar well.

All the injurious ingredients of the gas have now been removed except the sulphuretted hydrogen, which is removed in an apparatus called the purifier, which depends for its action on the affinity of sulphur for hydrated lime or iron. In good engineering practice the ferrous oxide of iron ($Fe_2\ O_3$) is used entirely. The iron is placed on trays, arranged in tiers, and the gas is conducted through these, and the resulting chemical action is as follows:

$$Fe_2\ O_3 + 3H_2\ S = 2\ FeS + S + 3H_2O.$$

Ferrous sulphide of iron, upon exposure to the atmosphere, absorbs oxygen, and its sulphur is separated in a mettallic form thus:

$$2\ Fe\ S + 3\ O = Fe_2\ O_3 + 2\ S.$$

From this you will observe that the cost of purifying the gas involves little expense, since the iron can be used continuously by exposing it to the air after it has been converted into the sulphide.

Having stated briefly the method of the manufacture of the gas, let us now consider the results which we obtain. Let us take, for example, ten (10) tons of bituminous coal. I take ten (10) tons since this is the amount of coal which is used in one

day of twenty-four (24) hours in two benches of six retorts each, in order to arrive at the cost of labor in generating the gas. The maximum yield of gas has been found practically to be about five (5) cubic feet per pound, so that the ten (10) tons of coal yield us one hundred thousand (100,000) cubic feet. We have obtained, however, in the process of distillation, several articles which are known as residuals or bi-products, and which are of some commercial value. We have obtained about sixty-five (65) per cent. of the original weight of coal in coke, or about thirteen thousand (13,000) pounds, twelve hundred (1200) pounds of tar, and about one thousand (1000) pounds of ammoniacal liquor. Of the thirteen thousand (13,000) pounds of coke, which we obtained, we will use about twenty-three (23) per cent., or three thousand (3000) pounds, to heat the retorts, which distill the coal. There remains then, ten thousand (10,000) pounds which we have no use for at the works, and therefore can dispose of to the best advantage. Coke-oven coke, which I designate by this name in contra-distinction to gas coke, is sold for about one (1) dollar per ton, so that we could, probably, not obtain more than eighty (80) cents per ton for gas coke, since it is of a spongy nature, and is therefore not so desirable. This will yield us then five times eighty (80) cents, or four (4) dollars. The twelve hundred (1200) pounds of coal tar, which is equivalent to about three and one-half (3 1-2) barrels, will yield one (1) dollar per barrel. We can not consider the value of the ammoniacal liquor since it will depend on the proximity of a chemical works. In this connection, I submit some figures which were obtained from a report of the various gas companies of London for 1875.

Cost of coal - - - -	£1,455,400
Received for coke and breeze -	492,927
Received for tar - - - -	162,161
Received for ammoniacal liquor -	111,951
Gas made - - - -	14,888,133 thousand feet.
Gas sold - - - - -	13,622,639 " "
Coal carbonized - - -	1,505,000 tons.
Coke sold - - -	69 per cent.

Average yield of gas, 9892 feet per ton.

From these figures we observe that the return from the sale of residuals has amounted to more than half of the original cost of the coal. This return varies greatly, depending on the ability of the engineer in charge, and the locality of the works. I have

it on the authority of one of the foremost gas engineers of the United States, who recently investigated the operations of the gas plant of Paris, France, that the returns from the disposal of the bi-products of the works were in excess of the original cost of the coal.

To resume: We have then to our credit one hundred thousand (100,000) cubic feet of coal gas, five (5) tons of coke worth four (4) dollars, three and one-half (3½) barrels tar worth $3.50. Let us now see what we have expended in producing these results. We have paid for:

Ten (10) tons of coal - -	at $2.00 =	$20.00
Wages of two chargers - -	at 2.25 =	4.50
Wages of two helpers - -	at 1.80 =	3.60
Wages of two engineers - -	at 2.00 =	4.00
Cost of two tons of coal for boiler	at 2.00 =	4.00
Cost of oils, etc. - - - -		0.50
Total - - - - - -		$36.60
Credit by sale of residuals - - - -		7.50
Cost in holder of 100,000 cu. ft. of gas -		$29.10
Cost per thousand cu. ft. - - - -		0.29

To this must be added the cost of superintendence, clerk hire and inspection, which is classed under the head of distsibution, and averages about twelve (12) cents per thousand feet, making the total cost forty-one (41) cents. This result is manifestly a variable quantity since there are certain expenses which will remain fixed, regardless of the quantity of gas which is manufactured, notably the cost of superintendence, clerk hire and engineers. There is a loss of about ten (10) per cent. of the gas in distribution, as you will observe in the discrepancy, of the report of the London works, between the gas manufactured and the gas sold, owing to poor workmanship in laying pipe lines, incorrect metre readings, condensations and differences in temperature. This will make our total cost 45 cents per thousand. To this must be added about 10 per cent. for wear and tear on machinery, cost of renewals, depreciation of plant, and interest on investment, making the total cost, delivered to the consumer, about 50 cents per thousand feet.

Let us now ascertain the value of our one hundred thousand

(100,000) cubic feet of gas. The average volumetric analysis of coal gas is as follows:

Hydrogen (H) - - -	46 per cent.
Marsh gas (CH_4) - - -	40 "
Carbonic oxide (CO) - -	6 "
Olefiant (C_2H_4) - - -	4 "
Nitrogen (N) - - -	1.50 "
Carbonic acid (CO_2) - -	0.50 "
Oxygen (O) - - -	0.50 "
Water vapor (H_2O) - -	1.50 "
Total - - -	100.00

From this we see that we have a gas yielding 96 per cent. combustibles of which the calculated theoretical calorific value is seven hundred and thirty-five thousand (735,000) heat units, per thousand feet. We therefore have in our one hundred thousand (100,000) feet of gas seventy-three millions five hundred thousand (73,500,000) heat units. The weight of one thousand (1000) cubic feet of this gas is about thirty-two (32) pounds, and the weight of the resultant gases from perfect combustion would be as follows:

Steam - - - - - -	69.7 pounds
Carbonic acid - - - - -	68.6 "
Nitrogen - - - - - -	427.2 "
Total weight after combustion -	565.5 "

Pounds of oxygen necessary for combustion 103

The flame temperature of this gas is found to be about forty-six hundred (4600) degrees Fabrenheit, and can readily be calculated theoretically, by means of this formula:

$$T = \frac{H+U}{WS}.$$

Where:

T = temperature

H = units of heat from combustion

U = units of heat carried in by air

W = weight of resultant gases of combustion

S = specific heat of resultant gases.

The theoretical calorific value of our ten (10) tons of coal is twenty-five (25) million times ten, or two hundred and fifty (250) million heat units. We have obtained in our gas seventy-three million five hundred thousand (73,500,000) heat units, or about

thirty per cent. of the efficiency of our coal. Assuming the efficiency of our gas-stove to be ninety-five (95) per cent., we will then utilize ninety-five (95) per cent. of seventy-three million five hundred thousand (73,500,000) heat units, which equals seventy million (70,000,000). We have previously found that if we consume ten (10) tons of coal in a stove we obtain fifty million (50,000,000) heat units. For these fifty million (50,000,000) heat units the consumer pays twenty (20) dollars in an indirect form of ten (10) tons of coal at two (2) dollars per ton. Putting the cost of our gas on the same basis as the cost of coal, we should receive for it seventy million (70,000,000) divided by fifty million (50,000,000) or 7-5 of the cost of coal, which equals twenty-eight dollars. This one hundred thousand (100,000) cubic feet of gas then must be sold for twenty-eight (28) dollars, or twenty-eight (28) cents per thousand feet.

In our previous calculations in regard to the cost of the gas we have found it to be fifty (50) cents per thousand. The company then would be obliged to sell an article for twenty-eight (28) cents per thousand, which cost them (50) cents per thousand. No further comment on the impracticability of utilizing coal-gas for a fuel-gas is necessary.

In future papers, I shall endeavor to show the impracticability of utilizing either water-gas or producer-gas for artificial fuel purposes, and shall also give the results of experiments concerning a gas composed of a mixture of the three gases; and finally the results of experiments concerning the production of water and producer-gas in the same apparatus.

A REVIEW OF THE NEW SIDE-WALK OF THE STONE BRIDGE ACROSS MONOCACY CREEK, BETHLEHEM, PA.

During the past year decided changes have been made in the appearance of South Main Street, in the Boroughs of Bethlenem and West Bethlehem; the most noticeable being the addition of a commodious and very substantial sidewalk to the eastern side of the stone bridge across the Monocacy Creek, connecting the above mentioned boroughs. As the creek is the dividing line between the counties of Lehigh and Northampton, the county commissioners decided to build this necessary structure in conjunction, and in the course of a few weeks, plans and specifications were prepared, and proposals for the construction of the same called for.

At the time agreed upon, the commissioners of the said counties opened the bids, and the contract for the iron works was awarded to Mr. L. L. Beckel for $730.80; the other bidders for the same, being the Allentown Rolling Mill Company, and the King Iron Bridge and Manufacturing Company of Cleveland, O.

Some time afterwards Mr. Beckel withdrew his bid, and at the next meeting of the commissioners the contract was re-awarded, and given to the Allentown Iron Company for $1075—this being the next lowest bid.

The old sidewalk, on the north-west side, is laid on wooden stringers, which are supported by large cast-iron brackets, fastened with bolts to the masonry of the bridge.

In the new sidewalk, on the south-east side, an extension of the piers was made, on the ends of which were placed a row of 15″ I beams, to which one end of a series of lighter I beams, or cross beams, are fastened by means of short pieces of angle iron; the other end of the said cross beams resting on the old masonry of the bridge. The wood-work is placed on top of these cross beams. The manner of construction being illustrated by Fig. 1.

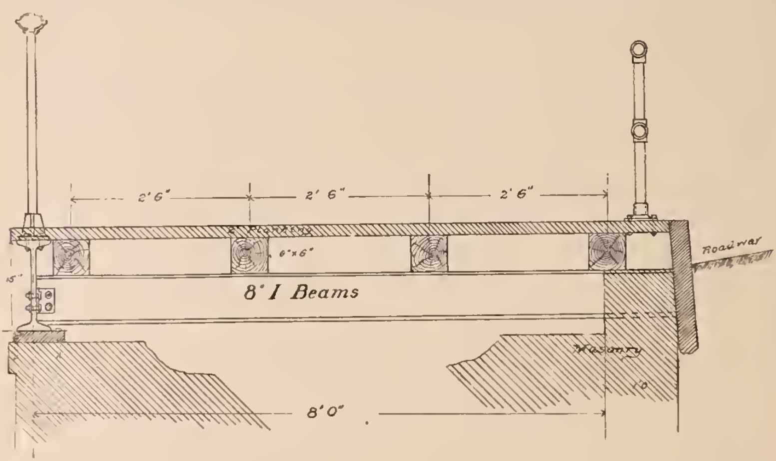


Fig. 1.

The longest span is about 32 feet, and, as the specifications called for the heaviest I beams that are rolled in this country, the question might have been raised, whether it would not be advisable to use either a plate or rivetted girder instead of an I beam, as the specifications required. The only way to decide such a question is to consider the loads to which the various parts of the

structure are subjected, and then to draw conclusions from the results obtained.

The cross-beams on which the wood work is placed have a clear span of 8 feet, and they are spaced 10 feet centre to centre, at right angles to the main I beams. The dead load per panel, consisting of the weight of the floor construction, plus the weight of the beam itself, is the following:

$$\left.\begin{array}{l}\text{Planks, } \frac{10\times8\times2}{12}=13.33 \text{ cu. ft. @ 34lbs. per cu. ft.}\\ \text{4 Stringers, } 0.5\times0.5+10=10.00 \text{ cu. ft. @ 34lbs. per cu. ft.}\end{array}\right\}=793$$

Assumed weight of beam 8 ft. long @ 16lbs. per lin. ft.=128

Total - - - - - - - - 921

Taking the live load as 80 pounds per square foot, the load supported by each beam is $10\times8\times80=6400$ pounds. The total load on each beam then is 7321 pounds. On account of the proximity of the beams, this load can with entire safety be taken as a uniformily distributed load, and the bending momemt is found to be $\frac{7321\times8\times12}{8}=87852$. Using a fibre strain of 12000 pounds per square inch, we find the required beam must have a moment of resistance of $\frac{87,852}{12,000}=7.32$.

Looking at a prominent manufacturer's table of I beams, we find that a 6″ light beam of 13½ pounds per foot has a moment of resistance of 8.16, which is more than sufficient; for such a beam will support with entire safety a uniformly distributed load of 8200 pounds.

This beam could have been used instead of an 8″ beam of 25 pounds per foot as the plans and specifications require, and an amount of iron saved on each beam equal to (25-13½)9=.103½ pounds, or the total amount in fourteen cross beams of 1449 pounds.

The heavy 15″ I beams reach from pier to pier and support one end of the cross beams that are spaced 10 feet centre to centre. As the span of these heavy beams is 32 feet the most dangerous application of the loads would be as indicated in Fig. 2.

As seen before, the load on each cross beam is 7321 pounds, one half of which is exerted upon the main I beams, and by adding the weight of the hand-railing we find the total load acting as a concentrated load to be 3700 pounds. We now find the bend-

ing moment for the loads in the position given in the figure, after assuming the weight of the beam to be 50 pounds per linear foot:
$M=(5500\times 16-3700\times 10)12+\frac{1}{8}(50\times 32)\ (32\times 12)=688{,}800.$

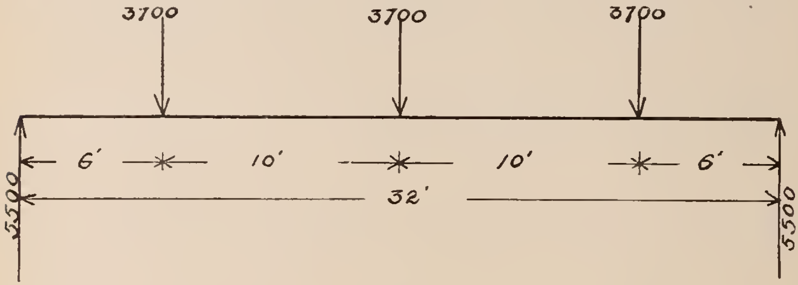


Fig. 2.

Allowing a fibre strain of 10,000 pounds, we have the moment of resistance equal to $\frac{688{,}800}{10{,}000}=68.88$. Referring to the table of beams we now find that a 15″ I beam of 50 pounds per linear foot has a moment of resistance of 70.6, and is therefore strong enough.

The specified beams, weighing 80 pound per foot, consequently have an unnecessary amount of iron in them, and in the total length of the I beams or 130 feet, 3900 pounds could have been saved. Assuming the price per pound of 6″ beams, punched and framed, including the erection, to be $3\frac{3}{4}$ cents, and in the case of the heavy beams 4 cents, the cost of the unnecessary material is $1449\times 3\frac{3}{4}+3900\times 4=\$210.34$. Therefore, as far as the safety of the structure is concerned, the kinds of material are well selected, but the cost of unnecessary material seems to be extremely large, being over 20 per cent. of the contract price.

In a structure of a greater magnitude this amount would not be noticed, but in this case more care should have been taken to render this improvement as economical as possible.

L. J. H. Grossart, '86.

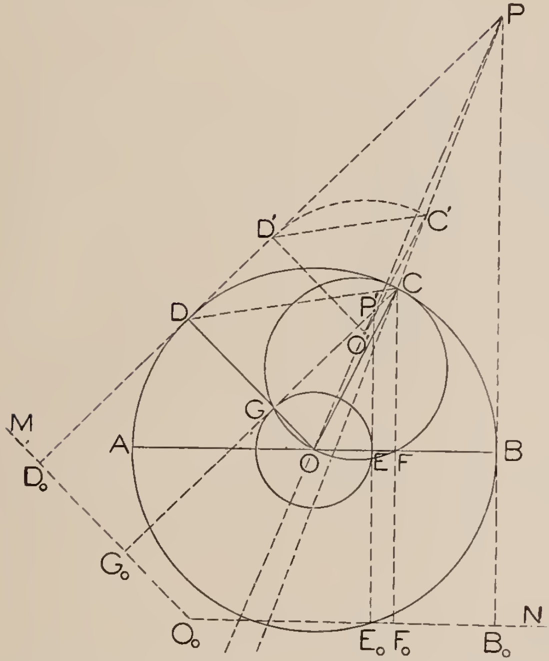
A GRAPHICAL SOLUTION OF A VALVE GEAR PROBLEM.

The following data are given:

1. Lead in linear measure.
2. Port-opening plus over-travel.
3. The rate of expansion i. e. position of crank when cut-off takes place.

To find:

1. Radius of the eccentric.
2. Outside lap.



Let $N\ O_o\ M =$ angle through which crank has passed when cut-off takes place. On NO_o lay of $E_oF_o =$ given lead and erect at E_o and F_o the indefinite perpendiculars E_oP^1 and F_oC. From any point C in F_oC let fall a perpendicular on MO_o intersecting MO_o in G_o and E_oP^1 in P^1. Make $D_oG_o = E_oB_o =$ port-opening plus over-travel and from D_o and B_o draw parallels to G_oC and F_oC respectively intersecting at P. Join PC and PP^1 and prolong the lines. PP^1 will bisect angle $D_oPB_o = \angle G_oP^1E_o$ and is a geometrical locus of the centre of the diagram. This centre is equally distant from C and PD_o. To find this point let fall from any point O^1 in PP^1 a perpendicular D^1O^1 upon D_oP. With D^1O^1 as a radius and O^1 as a centre describe an arc D^1C^1 intersecting PC in C^1. Join D^1C^1. From C draw a parallel to D^1C^1 intersecting PD_o in D. At D erect a perpendicular upon D_oP intersecting PO in O. From similar triangles it is easy to prove that $DO = OC$. OB parallel to O_oB_o is equal to DO according to construction. $DO = OC = OB =$ the required radius $GO = OE =$ the required outside lap.*

F. A. WEIHE, '90.

* An analytical solution of this problem is given on page 38 of "Zeuner's Treatise on Valve Gear," translated by Prof. J. F. Klein.

BIDONE'S EXPERIMENTS ON BACKWATER, OR *REMOU.*

INTRODUCTION.

[The following is a translation, slightly condensed, of experiments on the *remou*, by George Bidone, who first made precise observations upon this phenomenon. They were made in September and October, 1818, at the Hydraulic Laboratory of the Université Royale, and were published in 1819 in the proceedings of the Royal Society af Turin. The original measurements were taken in Paris *pieds*, *pouces* and *lignes*, which have been reduced to English measures by the writer. The old French, or Paris, *pied* was equivalent to 12.789 English inches.* A *pouce* was one-twelfth of a *pied*. A *ligne* was one-twelfth of a *pouce*;a *point*, one-twelfth of a *ligne*.

In the following pages, the writer has translated "*l'origene du remou*" by the single word *jump*. This word seems to be appropriate, as at that point, in Bidone's Experiments, the surface of the water was very suddenly elevated as by a veritable jump.]

The most simple case, which can be proposed for the formation of a *remou*, is that in which a canal of uniform section is obstructed from one side to the other by a dam at right angles to the current, placed on the bottom, and built to a height less than that of the sides of the canal, so that all the water can pass over the dam without escaping at any point. Such a barrier causes a backing of the water up stréam, and forces it to rise until the volume passing over the dam is equal to the discharge of the canal, which is supposed to be constant. Arriving at this height, the current once more reduced to a permanent state, confirms to the new condition of its bed. In this state, the backing of the water extends a certain distance above the dam, and every section of the stream taken in this distance has a greater depth than before the dam was established. This distance counted from the dam is called the extent of the *remou*. In order to leave no doubt as to the accuracy of the results obtained, straight rectangular channels were used, and the slope of the bottom and the velocity of the water were so great as to cause all the circumstances of the phenomena to be distinctly marked.

* See Johnson's Encyclopedia.

It was noticed that, 1st, the extent of the *remou* was always less than the distance to the point where the horizontal drawn through the highest point of the *remou*, intersects the natural surface of the stream, and 2nd, the surface of the water throughout the entire extent of the *remou* was always convex. This convexity, being very slight in the middle, increased rapidly near the ends where it became quite marked. These results, which were constantly obtained in all the experiments, were exactly opposite from what had heretofore been imagined by other authors. It must also be stated that the conditions were such that the water could make no deposits in the bed of the canal.

MANNER OF CONDUCTING THE EXPERIMENTS.

(1) The first operation was to introduce and maintain in the canal a known quantity of water, and to give it time to take a well established and permenent flow. This done, measurements were made above the spot where the dam was to be placed, of the depth of the water in different sections more or less distant from this point. The depth in each section was taken at three places, near each side and in the middle of the canal. The mean of these three measurements was recorded as the depth of the section, in the table of experiments. In these and other analogous measurements, fractions of a *ligne* were always taken into account.

(2) Next the dam was put in position. It was fitted into grooves formed in the bottom and sides of the canal, and was placed perfectly vertical, and perpendicular to the sides. The edges of the dam were coated with a cement, which prevented any leaking of the water through the grooves, and so the entire discharge of the canal was forced to pass over the top of the dam. Each dam was made of a single piece of strong wood, well planed, and about one inch in thickness. The dam being thus firmly fixed, its height above the bottom was measured in three places, at each side and at the middle, and the mean taken and recorded as the height of the dam.

(3) After the current had once more settled into a state of permanency, relative to the new condition of its bed, the depth of the water was measured a short distance above the dam. Then the distance from the dam to the jump, the place where the surface of the water rises very abruptly, was determined. This jump was

very distinctly marked, and the plan and elevation of it is shown in the accompanying figure.

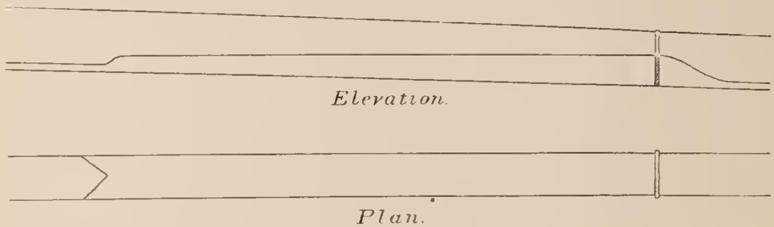


Fig. 1.

The distances recorded in the tables refer to the extent of the *remou* near both sides of the canal and also in the middle of the stream. Finally the depth of the water in a section a little above the jump was measured in order to see whether the depth of this section was affected by the *remou*. The results of these measurements will be found noted in the remarks.

(4) After having finished the above operation, the dam was removed and replaced by a higher one, still preserving in the canal the same volume of water. Then all the preceding operations were gone through with, for this new dam, and this new state of the water. The height of the dams was thus increased from one experiment to another. In all cases the height of each dam above the bottom of the canal was such that the fall of the water over the crest was perfectly free, that is to say, the depth of the water below the dam was never as great as the height of the dam.

(5) After having observed the *remou* produced by dams of successively greater heights, the discharge of the canal remaining constant, the volume was changed, and a new set of experiments was commenced in the same canal, by using successively the same dams, and performing on each of them the same operations previously described. Finally a similar set of experiments was made in another canal of a different slope from that of the first.

(6) These canals were originally constructed with uniform slopes. But repairs which were afterwards made had altered the original inclinations. This alteration was hardly appreciable, and for any other purpose might be neglected, and the mean slope taken, which differed very little from the primitive; but for experiments on the *remou*, it was believed best to take the actual

profile of the bottom of each of the canals, and to note the different inclinations at points near enough to each other, so that the slope from any point to the one following might be regarded as uniform. These profiles were taken with the water at rest. The uniform width of the canals was twelve *pouces* (1.066 feet.) The bottom and sides of the canals were built of masonry and the sides were exactly vertical and perpendicular to the bottom.

(7) These canals are designated as No. 1 and No. 2. The profiles of their beds are referred to the horizontal passing through the point in the bed where the dam was established. The abscissas are positive up stream and negative down stream from the dam. The ordinates are positive above and negative below the axis of abscissas.

TABLE OF PROFILES.

PROFILE OF BOTTOM OF CANAL NO. 1.		PROFILE OF BED OF CANAL NO. 2.	
Abscissas Feet.	Ordinates Feet.	Abscissas Feet.	Ordinates Feet.
+36.616	+ 1.221	+16.608	+ 1.025
+31.980	+ .984	+ 0.888	+ .052
+25.584	+ .744	0.000	.000
+19.188	+ .533	− 6.394	− .403
+12.789	+ .302		
+ 6.394	+ .138		
+ 3.197	+ .062		
0.000	.000		
−19.188	− .373		

It will be seen by these profiles that the beds of the canals are composed of a succession of planes differently inclined to the horizon. These profiles were taken only over a distance sufficient to measure the extent of the *remou*, and to observe its influence on the course of the water. In all the experiments the greatest distance to which the *remou* extended above the dam was less than 21 *pieds* (22.3 feet) in canal No. 1, and less than 13 *pieds* (13.9 feet) in canal No. 2.

[The two following tables contain the results of the experiments. Bidone gives them in four sets of two tables each, but the translator has compiled them, together with all accompanying remarks, into two. Table II represents the condition of things for the different sets of experiments, before the dams were put in position. Table III contains the results which were obtained after the dams were put in place.]

TABLE II.

No. of Canal.		Distance from Dam to Point up Stream where Depths were measured.	Depth of Water in each Section.	Mean Velocity in each Section, calculated from Discharge of Canal and Area of Section.	Constant Discharge of Canal.	Constant Width of Canal.
		Feet.	Feet.	Feet.	Cu.ft.per sec	Feet.
No. 1.	Set I.	6.395	.144	4.7900	.7339	1.066
		12.790	.154	4.4822	......	......
		19.185	.156	4.4114	......	......
		25.580	.145	4.7492	......	......
No. 1.	Set II.	6.395	.206	5.6716	1.2416	1.066
		12.790	.209	5.5713	......	......
		19.185	.213	5.4903	......	......
		25.580	.194	5.9957	......	......
No. 1.	Set III.	6.395	.252	6.1208	1.6497	1.066
		12.790	.244	6.3531	......	......
		25.580	.237	6.5522	......	......
No. 2.	Set IV.	6.395	.151	4.5371	.7273	1.066
		12.790	.149	4.5905	......	......
		19.185	.132	5.1456	......	......

In the 3rd experiment of Set I. the depth of the stream at 21.3 feet above the dam was measured, both while the *remou* existed and after the dam had been removed, and was found to be the same both times, viz.: $d = 0.156$ feet.

In Experiment 5, of Set II., the same operations were performed 22.3 feet above the dam, and the resulting depth each time was found to be $d = 0.213$ feet.

In Experiment 3, of Set III., the resulting depth both times was $d = 0.245$ feet at 15.9 feet above the dam.

In Experiment 1, Set IV., the same phenomenon was observed, the constant depth being $d = 0.149$ feet at 9.6 feet above the dam.

In the experiments made with canal No. 1, the highest point of the *remou* occurred at 3.2 feet up stream from the dam. The surface of the *remou* on both sides of this place was very slightly convex except near both extremities, one at the dam and the other at the jump, where the convexity increased rapidly and became very marked. Fig. 1 represents the profile and plan of the canal and of the current for the first experiment of Set 1.

TABLE III.

No. of Canal.		No. of experiments in each set.	D Height of Dam above bottom.	B Height of Surface of *Remou* compared with Top of Dam taken at Highest Point of *Remou*.	F Extent of *Remou*, at the Right Side of Canal.	in the Middle.	at the Left Side of Canal.	Length of Horizontal drawn through Highest Point of *Remou* counted from Dam to where it meets the Natural Surface of the Stream.
			Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
No. 1.	Set I.	1	.440	.335	14.714	14.178	14.899	21.937
		2	.524	.330	16.786	15.987	16.831	24.424
		3	.617	.335	19.163	18.711	19.361	27.178
		4	.710	.333	22.168	21.435	22.093	29.665
No. 1.	Set II.	1	.446	.450	12.523	12.078	12.657	24.157
		2	.527	.459	14.731	14.564	14.988	26.822
		3	.620	.469	17.430	17.141	17.586	29.576
		4	.704	.471	19.717	19.272	19.849	31.884
		5	.794	.468	21.937	21.670	21.937	33.749
No. 1.	Set III	1	.441	.553	11.153	11.012	11.301	25.933
		2	.527	.550	13.463	13.419	13.618	28.244
		3	.615	.548	15.660	15.424	15.913	30.551
No. 2.	Set IV.	1	.636	.282	9.147	8.460	8.984	11.80
		2	.716	.284	9.910	9.637	10.414	13.86
		3	.796	.308	11.716	10.969	11.554	15.54
		4	.886	.316	13.411	12.592	13.021	17.23

For the experiments made in canal No. 2, the highest point of the *remou* was about 10.5 inches up stream from the dam, and the surface of the *remou* had the same form as described above. These operations were gone through with for the other sets of experiments.

From an inspection of these tables, and of the profiles of the canals in which the experiments were made, we see:

1st. That the extent of the *remou* is always less than the distance to the point where the horizontal drawn through the highest point of the *remou* meets the natural surface of the stream.

2nd. From the first three sets relative to Canal No. 1, we see that in proportion as the depth of the section and mean velocity of the current is increased, the extent of the *remou* for the same dam diminishes. This can be easily seen from the following table, which contains the first three experiments of each of the first three sets, with the corresponding discharge of the canal,

the mean velocity of the current, the height of the dams, and the extent of the *remou* in the middle of the stream.

Sets.	Experiments.	Height of Dams above the Bottom.	Constant Discharge of Canal.	Depth of the Section at the Jump in the Middle of Stream.	Mean Velocity of Current in the Section at the Jump.	Extent of the *Remou* in the Middle of the Stream.
		Feet.	Cu. ft. per sec.	Feet.	Feet per sec.	Feet.
I	1st	.440	.7337	.155	4.4643	14.178
II	1st	.445	1.2416	.209	5.5878	12.078
III	1st	.442	1.6497	.246	6.2895	11.012
I	2nd	.524	.7337	.150	4.4465	15.987
II	2nd	.527	1.2416	.210	5.5550	14.564
III	2nd	.528	1.6497	.243	6.3531	13.419
I	3rd	.615	.7337	.158	4.4114	18.711
II	3rd	.620	1.2416	.211	5.5225	17.141
III	3rd	.614	1.6479	.241	6.3855	15.424

The dams shown in this table have, three and three, the same height, and we can see that the extent of the *remou* for the same dam is less as the depth of the section and mean velocity of the current are greater.

3rd. The extent of the *remou* is less in the middle of the stream than at the sides of the canal.

4th. We see from the experiment notes in the column of remarks that the sections of the current taken a little above the jump suffer no sensible alteration, and preservcs the same depths which they had before the dam existed, and the flow of the water in the canal was unobstructed.

5th. Finally the surface of the water throughout the entire extent of the *remou* was always convex; this convexity, very slight in the middle, increased rapidly near both ends, where it became considerable. The junction of the natural surface of the stream with the convex surface of the *remou* took place over such a very short distance that the origin of the *remou* was very distinctly marked, the convex surface being suddenly elevated, as by a jump, above the natural surface of the stream.

SAM. W. FRESCOLN, C. E., '88.

ABSTRACT OF PROCEEDINGS.

Feb. 26, 1889.—The President in the chair at 16:15 o'clock, with thirty members present. Mr. J. S. Riegel, '90, was elected to membership. An amendment to the constitution was proposed, providing for the election of an Assistant Business Manager. Mr. J. F. Merkle, '84, read a paper on "The Impracticability of using Coal Gas as a Fuel," for which he received a vote of thanks from the Society.

April 2.—The Secretary in the chair at 16:20 o'clock, and twelve members present. On motion it was decided to meet at 19 o'clock Mondays, until otherwise ordered.

April 15.—The Secretary in the chair at 19:20 o'clock, with fifteen members present. Mr. Throop, '89, resigned as editor of the JOURNAL, and Mr. Diebitsch, '89, was elected in his place. Mr. Merkle delivered a very interesting talk on "The Manufacture of Fuel Gas," for which he was tendered the thanks of the Society.

A. W. STOCKETT, Sec'y.

EDITORIALS,

IT IS with great regret that we announce the resignation of Mr. A. T. Throop, '89, as editor of the JOURNAL, with which he has been associated for the past two years. The increase in size and circulation of the JOURNAL is largely due to his untiring energy and zeal. Mr. Throop, having nearly completed his work at the University, has accepted a position as Assistant Superintendent of the construction of water works at Clyde, New York, His address, at present, is, Care of Water Works Co., Bath, N, Y.

C. W. HUDSON, '89, has completed his work at the University, and has accepted a position with Mr. F. P. Spalding, C. E., '80, who is in charge of the surveys of the third district of the Mississippi River Improvement. Mr. Hudson was one of the most active members of the ENGINEERING SOCIETY, and took great interest in its proceedings. His address is Wilson's Point, La.

ALUMINI NOTES.

1876.

—Walter P. Rice, C.E., the City Engineer of Cleveland, O., was declared elected a member of the American Society of Civil Engineers at the meeting on March 6.

1877.

—Charles R. Rauch, A.C., of Baltimore, Md., was married on February 5. to Miss Georgia Emmart of the same city.

1880.

—John T. Jeter, E.M., has resigned his position with the Lehigh Valley Coal Co., and has been appointed Engineer of the Rock Hill Granite Co., with headquarters at Bethlehem, Pa.

1885.

—Theodore W. Birney, C.E., has located at Atlanta, Ga., as an Attorney at Law.

1886.

—Augustus S. Ross, M.E., is with the Cycle and Pulverizer Co., New York City.

—John H. Spengler, C.E., is connected with the Engineering Department of the Artesian Water Company of Memphis, Tenn.

—Simeon C. Hayzleton, E.M., resigned his position as Instructor in Mining at the University in February, and went to Sandy, Utah, where he accepted a position with the Mingo Furnace Company.

—Theodore Stevens, E.M., has resigned his position as Chemist to the Cowles Electric Smelting and Aluminum Company of Lockport, N.Y., and has gone to the Exposition at Paris in the interest of a number of exhibitors. His address is Lock Box 22, U. S. Section, Universal Exposition, Paris, France.

1887.

—W. Hampton Woods, B.S., is with the Thomas Iron Company at Hogendauqua, Pa.

—Mason D. Pratt, C.E., of Johnstown, Pa., was on March 14, married to Miss Mabel Crane, at Jamestown, N. Y.

—Milton H. Fehnel, B.S.. has completed his course of post-graduate studies leading to the degree of A.C., and has accepted a position with E. C. Knight & Co., Sugar Refiners, Philadelphia, Pa.

1888.

—Wilner M. Webb, M.E,, is employed by the Hoopes Bro. & Darlington Company of West Chester, Pa.

—Winter L. Wilson, C.E., is on the Engineer Corps of the Pennsylvania Railroad, and is stationed at Wilmington, Del.

—Howard H. McClintic, C.E., is with Wilkins & Powell, Engineers and Architects, Rooms 20 & 21, McCane Block, Pittsburgh, Pa.

—George A. Hart, M.E., declined the offer as draughtsman in the office of the Chief Engineer of the Georgia, Florida & Western R. R., and accepted a position in the Ordinance Department of the Bethlehem Iron Company.

—Shuntaro Yamaguchi, C.E., who has been studying the construction and management of railroads with the Pennsylvania Railroad Company at Pittsburgh, returned to the University a few days ago, and passed the post-graduate examinations leading to the degree of M.S. Mr. Yamaguchi will sail for Europe in a few days, and after a brief sojourn on the Continent, will return, by way of the United States, to Japan, where he intends to devote himself to the management of railroads.